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Air-cooled heat exchanger operation under emergency cooling service

One of the challenges in the operation of air cooled heat exchangers (ACHEs) is to decide whether or not to operate under natural convection. There is limited information available for the simulation of an ACHE with no fans under operation. Under emergency conditions, such as fan failures or when bringing the ACHEs onstream from standby conditions to meet emergency cooling requirements, with none of the fans operating, the use of natural convection becomes unavoidable. This article discusses case studies to evaluate the pros and cons of both options:

1. Operating with fans running on emergency power
2. Operating in natural convection with none of the fans operating to meet the emergency duty conditions.

ACHE under natural convection. Simulation of ACHE performance under natural convection has the following limitations:

- **Non-availability of sufficient experimental data:** Most of the available experimental data based on wind tunnel tests are applicable for the large natural draft cooling towers with high natural draft velocity and are not applicable for ACHEs in process industries with relatively smaller sizes and lower natural draft velocity.
- **Impact of structures, heat source, local wind velocity and ground effect:** All these factors affect the natural draft by impacting the velocity of air at the exit of the ACHE. None of the available thermal design software considers these parameters in sizing an ACHE. Therefore, a detailed computation fluid dynamic (CFD) analysis, with its associated impact on project cost and time, is required to properly simulate the impact of natural convection.
- **Effect of chimney (stack) on the performance:** It has been established that the use of a chimney (stack) on top of the air cooler bundle (for forced draft unit) and on top of the fan ring (for induced draft unit) enhances the effectiveness of heat transfer due to natural convection. However, it is still a work in progress as far as the exact relationship of chimney height with natural draft performance is concerned.

Initial proposition: Avoid natural convection and use emergency power. In view of the challenges highlighted in simulating ACHE performance under natural convection, three services were proposed to operate the ACHEs during emergency conditions with the fans running on emergency power (**TABLE 1**). This operation allows achieving higher airside velocity, resulting in a higher mean temperature difference and higher airside heat transfer coefficient. As a result, the capital cost is reduced by decreasing the number of bays and/or heat transfer surface area vs. the natural draft option.

How dependable is emergency power? For emergency cooling scenarios, the likelihood of fan motor failure at startup was reviewed for the following four conditions:

1. Will the emergency cooling scenario with all fans off be the governing case?
2. If the above is true, can emergency cooling be met with the help of emergency power, which is being provided as backup power for the process unit, to power the fan motors during startup?
3. Will there be a case of double jeopardy when the motors may fail to start even with emergency power?
4. If double jeopardy is a possibility, can the air cooler

TABLE 1. Three service cases for ACHE usage during emergency conditions

Service #	Case of operation	Fans in operation	Cooling mechanism	Remarks
1	Normal operation	All	Forced draft	Controlling case: Fans on normal power
1	Emergency cooling	1 out of 4	Forced draft	Alternate case: Fan on emergency power
1	Emergency blowdown	1 out of 4	Forced draft	Alternate case: Fan on emergency power
2	Normal operation	All	Forced draft	Controlling case: Fans on normal power
2	Emergency cooling	2 out of 3	Forced draft	Alternate case: Fan on emergency power
3	Normal operation	All	Forced draft	Controlling case: Fans on normal power
3	Emergency cooling	1 out of 6	Forced draft	Alternate case: Fan on emergency power

meet the specified duty by operating under natural convection?

A closer review of the four conditions and the experience of similar applications revealed that double jeopardy is indeed a possibility. This will not only make the use of emergency power for operating the ACHEs under emergency cooling scenarios unacceptable, but will also result in the emergency cooling case—under natural draft instead of forced draft with 1 of the 4 fans operating—becoming the controlling case. Instead of normal operation, the emergency cooling case will govern the overall size of the ACHE.

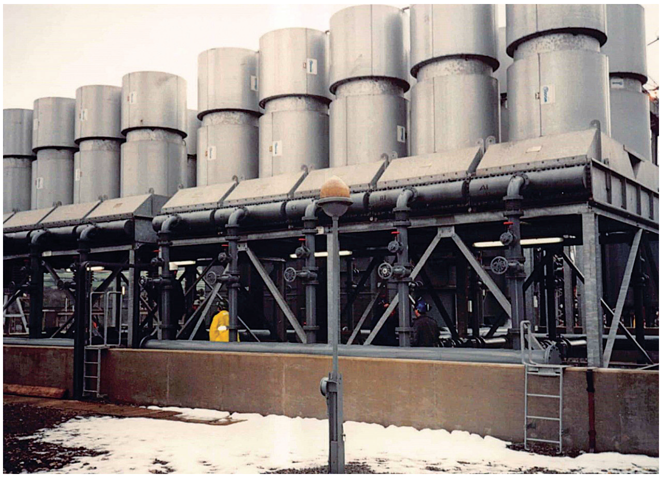

FIG. 1. Induced-draft ACHE with chimney. Photo courtesy of Spiro-Gills.

Final options—Natural draft with or without chimney. To size the ACHE for the controlling case (i.e., emergency cooling scenario) and to arrive at a final configuration of the ACHE, the following two possible options were reviewed. The simulation was carried out using standard commercial heat transfer software[a].

Option 1—Natural convection without a chimney: Increase the heat transfer area to take care of the loss in overall heat transfer effectiveness—due to natural convection—by increasing the number of bundles/bays and the number of bays over and above those required for normal operation case. In addition, increase the number of tube rows—over and above those required for the normal operation case—to increase the stack effect and facilitate natural draft.

Option 2—Natural convection with a chimney: Increase the velocity of natural convection over the ACHE bundles by providing a chimney (stack) on top of the bundle without increasing the number of bundles and bays from those required to cater to the normal operation cases.

The results of the two options, along with the initial option, are summarized in **TABLE 2.** Since Option 2 requires less plot space and lower surface area for all three services, it was preferred over Option 1.

Type of draft: Forced or induced. The chimney can be located either on the top of the tube bundles when fans (which are required for normal operation) are below the bundle (forced draft), or on top of the fan ring when fans are above the bundle (induced draft) (**FIG. 1**).

TABLE 2. Evaluation of various options

Service No.	Option	Controlling case	Type of draft	Bare area, m^2	No. of bays	No. of bundles per bay	No. of tube rows	Tube length, mm	No. of fans per bay/ total fans	Plot area, m x m	Chimney height, mm
1	Initial	Normal Operation[1]	Forced	591	2	2	5	11,000	2/4[1]	11 × 10	Not applicable
1	1	Emergency cooling[2]	Natural	4,968	9	2	8	11,000	–	54 × 10	No chimney
1	2	Normal operation[2]	Natural	555	2	2	4	11,000	–	12 × 10	4,000
2	Initial	Normal operation[3]	Forced	176	1	1	4	11,000	3/3[3]	3.6 × 11	Not applicable
2	1	Emergency cooling	Natural	5,433	10	1	12	11,000	–	39 × 11	No chimney
2	2	Emergency cooling	Natural	184	1	2	2	11,000	–	7.8 × 11	7,000
3	Initial	Normal operation[4]	Forced	851	3	2	6	11,000	2/6[4]	12.5 × 11	Not applicable
3	1	Emergency cooling[5]	Natural	2,726	6	2	9	11,000	–	27 × 11	No chimney
3	2	Normal operation[5]	Natural	912	3	2	6	11,000	–	14 × 11	3,000

[1] For the emergency cooling case, only 1 of 4 fans will be in operation, and the fan motor will be on emergency power.

[2] Emergency cooling, with all fans off and without a chimney, is the controlling case. However, with all fans off and with a 4,000-mm chimney, normal operation is the controlling case.

[3] For the emergency cooling case, only 2 of 3 fans will be in operation, and the fan motor will be on emergency power.

[4] For the emergency cooling case, only 1 of 6 fans will be in operation, and the fan motor will be on emergency power.

[5] Emergency cooling, with all fans off and without a chimney, is the controlling case. However, with a 3,000-mm chimney, normal operation is the controlling one.

The induced draft option, with a chimney on top of the fan rings, has the following advantages over the forced draft option:

- **A lower chimney height:** The induced draft design provides sufficient draft to allow the advantage of using a lower height chimney.
- **A lower impact of prevailing wind on ACHE performance:** In the induced draft configuration, the cross-sectional area of the fan ring is lower vs. the bundle face area (which is almost 2.5 times the fan area) in case of a forced draft ACHE. As such, a relatively higher exit velocity results in a low impact of prevailing wind on ACHE performance.
- **Better protection of the tube bundles:** The induced draft design protects the tube bundles from heavy rain and weather elements, with the plenum chamber on top of the tube bundle. Therefore, a removable protective roof for tube bundles is not required with an induced draft design.

Based on the overall advantage of operation, it was recommended to select Option 2 with induced draft configuration for all the three services.

Takeaway. Natural convection, in combination with forced or induced draft, is preferred over emergency power configuration for applications where an ACHE must be put into operation quickly from standby mode due to process consideration. The following points must be reviewed in detail before finalizing an ACHE configuration:

- Consider the limited availability of performance data of an ACHE under natural convection in process industry applications. The various pros and cons of the natural draft option with respect to other forms of operation (e.g., operating the ACHE fan motors under emergency power mode) must be reviewed during the project definition phase before finalizing the optimum mode of operation.
- The type of draft, whether forced or induced, to be adopted in combination with the natural convection mode should be decided based on the site condition (e.g., prevailing wind direction, presence of heat sources in the vicinity and annual rainfall) and specific customer requirements.
- The limitations of available software for ACHE performance simulation must be considered before deciding whether a detailed CFD analysis will be required to simulate the performance of the ACHE under natural draft conditions.

NOTE

[a] Heat Transfer Research Institute's X_{ace} software

RITABRATA PRAMANIK has more than 35 yr of experience in working with Engineers India Ltd., Bechtel, Foster Wheeler and Fluor Daniel in the design and engineering of heat transfer equipment in the oil and gas, petrochemical, LNG, fertilizer, chemical and power sectors. Presently, he is working as an independent consultant.

LIVE WEBCAST:
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Navigating the Sustainability Shift in Capital Projects

With an intense focus on decarbonization to achieve net zero, Engineering, Procurement & Construction firms (EPCs) and their clients will need to reallocate capital to take advantage of this new opportunity, raising questions such as:

- What sustainability areas will projects concentrate on most?
- How are companies organizing to react?
- What are the challenges?
- What are the opportunities?

These are just a few of the questions that we asked your peer companies in an online survey to better understand the strategies and actions decision makers are taking to successfully navigate the energy evolution and circular economy. Within the next five years, 60% of respondents believe that over 40% of their work will be in the sustainability area. The hottest project areas are in energy efficiency, carbon capture and hydrogen economy. In executing these new projects, the biggest barrier cited by 44% of the respondents was building a staff with the right domain expertise; the second largest barrier cited was the economics of the projects themselves.

Please join our panel as they discuss all of the survey findings and provide their unique insights. There will be a Q&A session following the event.

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